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Earth's Magnetosphere

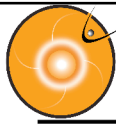


Space
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Research
Center

Space Weather Training
By: Dr. Yari Collado-Vega

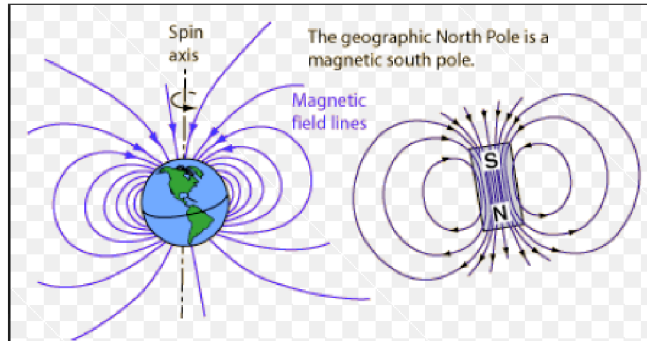
In this presentation I will be talking about the Sun and its activity in relations to the space weather

(http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Glossary/_space_weather)



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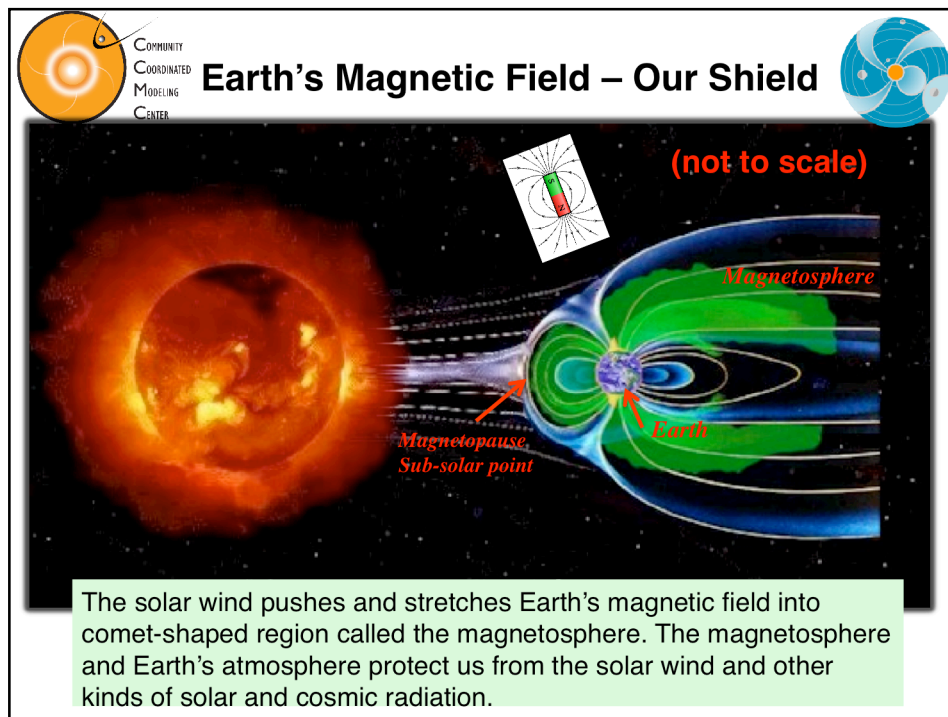
Magnetic Field of the Earth



The Earth's magnetic field is similar to that of a bar magnet.
The magnitude varies over the surface of the Earth in the
range 0.3 to 0.6 Gauss.

The Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth.

The magnitude of the magnetic field varies over the surface of the Earth in the range 0.3 to 0.6 Gauss.



The solar wind pushes and stretches Earth's magnetic field into a vast, comet-shaped region called the magnetosphere. The magnetosphere and Earth's atmosphere protect us from the solar wind and other kinds of solar and cosmic radiation.

Solar wind – Earth's magnetic field field interaction flatten the nose (dayside – towards the sun) and drag field lines to the tail (night-side – away from the sun).

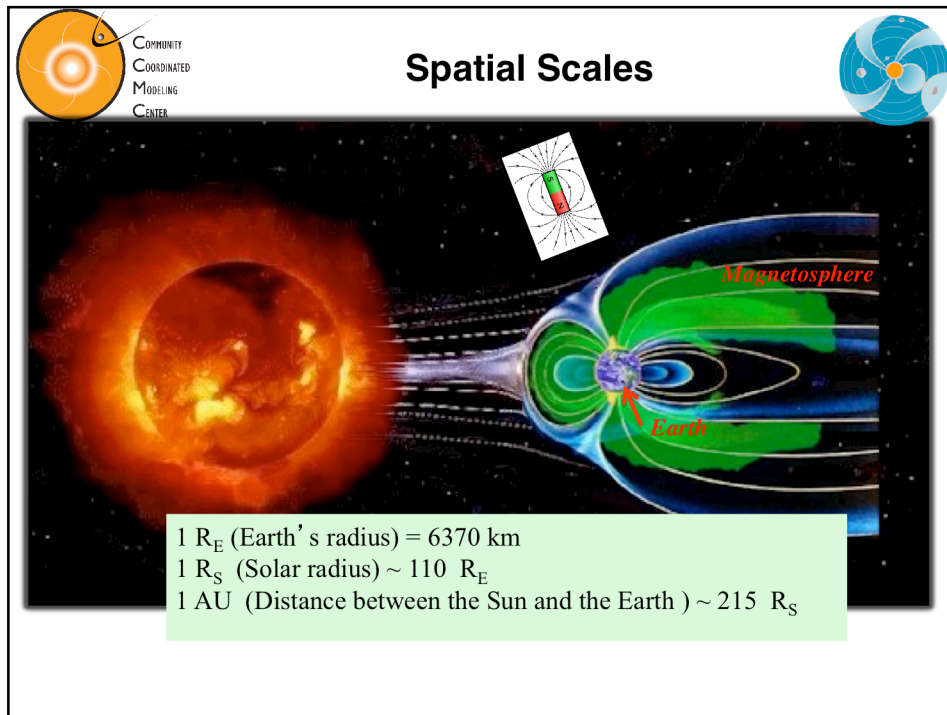
The magnetopause separates Earth's magnetic domain from the solar wind and its embedded interplanetary field (IMF).

The three-dimensional location of the magnetopause represents a balance of pressures: Pressures of solar-origin (predominantly solar wind flow ram pressure) balance pressures of Earth-origin (predominantly outward magnetic pressure) at the magnetopause.

The magnetic field is the shield that protects the Earth from the solar plasma particles because they have difficulty in moving across the magnetic field lines.

If the Earth did not have the magnetic field, continuously blowing solar wind and CMEs would most likely wipe out all the life forms on the Earth. Scientists speculate that something like this could have happened on Mars, who lost its magnetic field over the time.

The Sun-Earth line cross the magnetopause at the Sub-solar point. Magnetopause stand-off distance is the distance to the magnetopause sub-solar point.



Distances in Solar Corona are expressed in Solar radii: 1 – 20 R_S

Solar radius is approximately 100 times larger than the Earth's radius.

Distances in magnetosphere are expressed in Earth radii.

During quiet solar wind conditions the sub-solar point of the magnetosphere boundary is at about 10 R_E from the Earth.

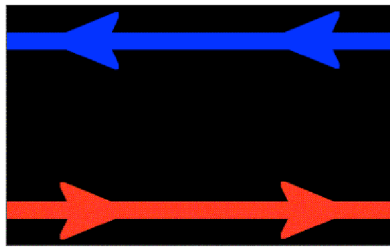
The tail width is about 30-40 R_E . The tail length is 1000s R_E

The distance to the moon is about 60 R_E ,

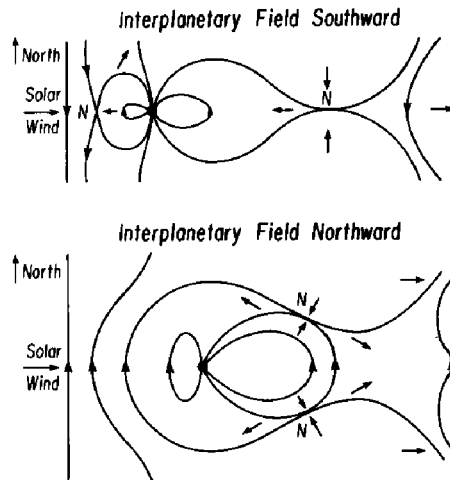


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Magnetosphere for Southward and Northward IMF Orientation

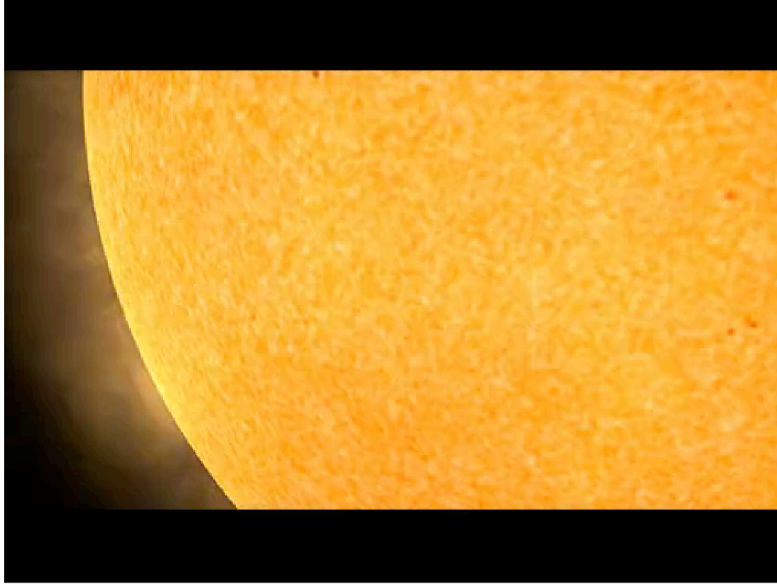


Magnetic Reconnection





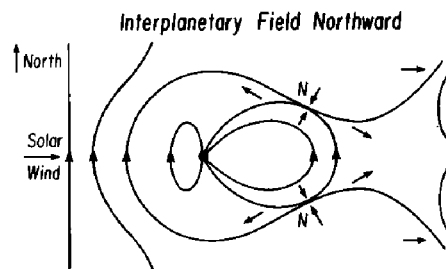
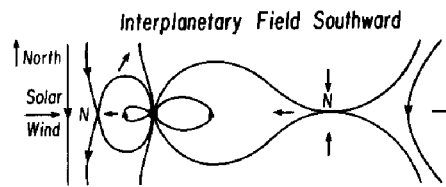
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Magnetosphere for Southward and Northward IMF Orientation





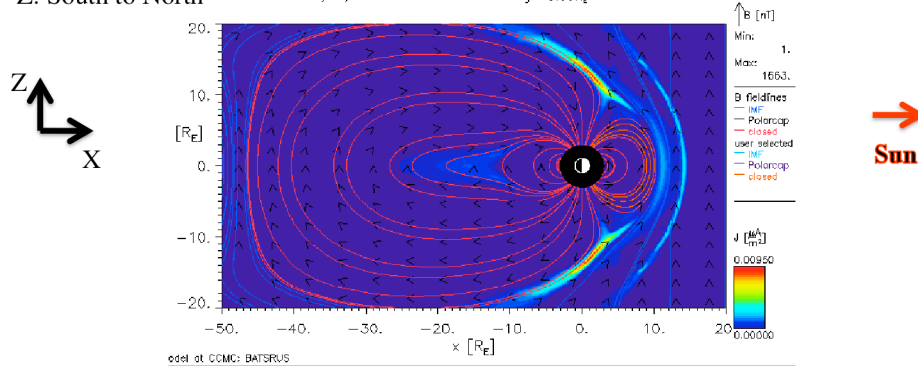
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Magnetosphere: Northward IMF

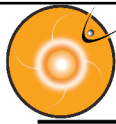


X: Earth to Sun
Z: South to North

01/01/2000 Time = 02:04:00 UT $y = 0.00R_E$

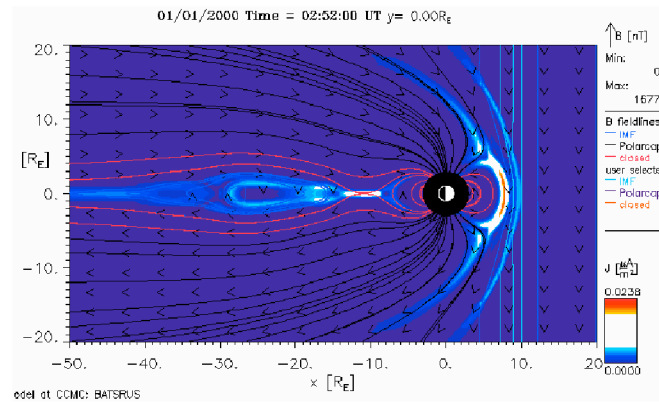


Red lines (closed): Magnetic field (MF) lines with both ends connected to the Earth
Black lines (open): MF lines with only one end at the Earth
Blue lines (interplanetary): MF lines with both ends in the interplanetary space



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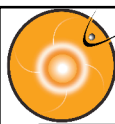
Magnetosphere: Southward IMF



Red lines (closed): Magnetic field (MF) lines with both ends connected to the Earth

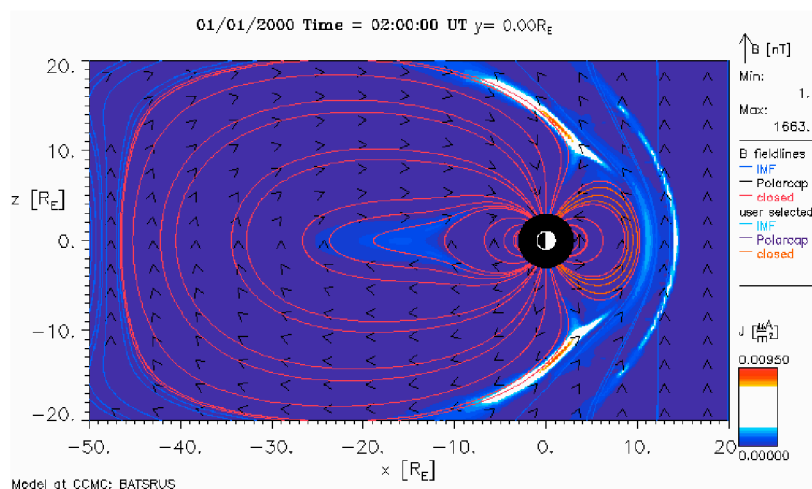
Black lines (open): MF lines with only one end at the Earth

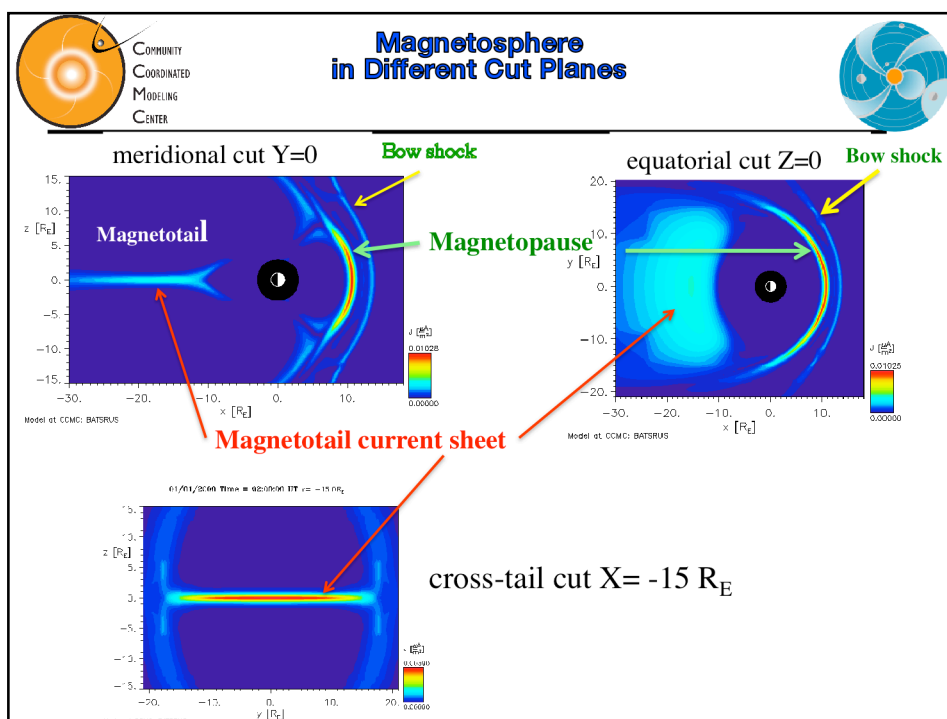
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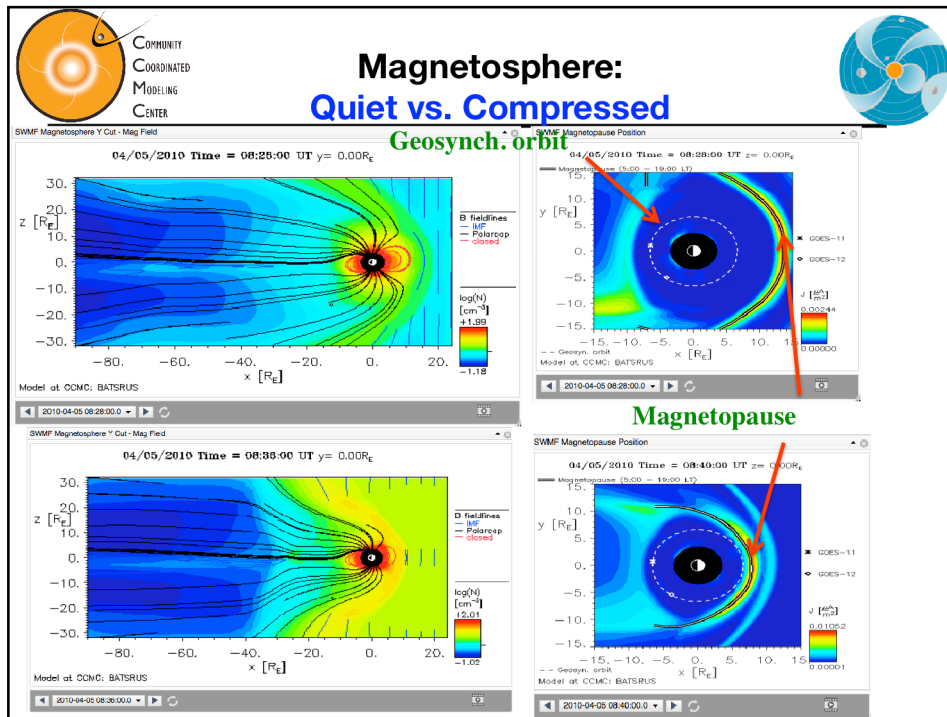


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Magnetosphere: North to South Turning









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Magnetopause Stand-off Distance



Degree of compression of MP
Due to Pdyn of solar wind
(interplanetary shock or HSS)

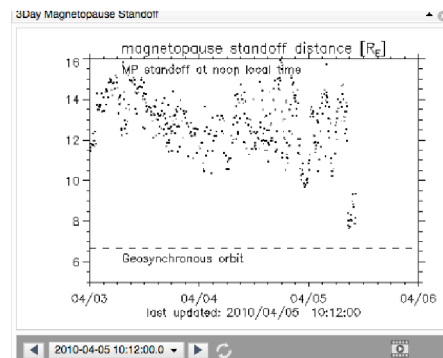
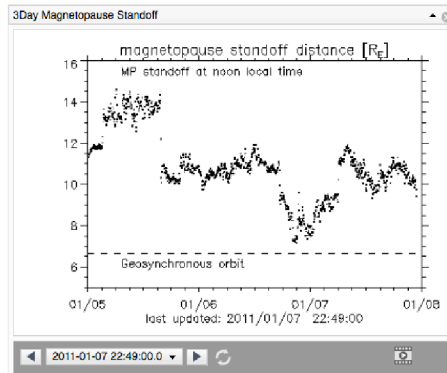
$r_0 \leq 6.6 R_E$ – model product

Events: Apr 5, 2010,

Dec 28, 2010

Jan 6, 2011, 22:30 UT

Non-event: Dec 1 – 7, 2010





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Kp



"planetarische Kennziffer" (= planetary index).

- Geomagnetic activity index

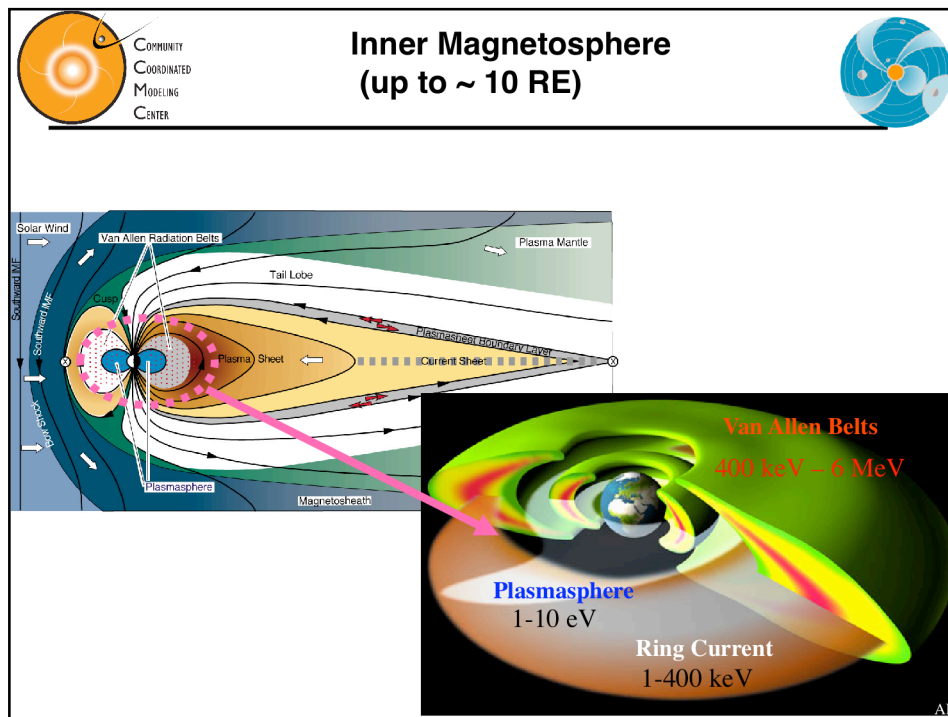
range from 0-9 disturbance levels of
magnetic field on the ground - currents

1. Non-event - period of 12/01/2010 – 12/7/2010
2. Moderate event – April 5, 2010
3. Extreme event - Oct 29 – Oct 31, 2003

http://bit.ly/Kp_layout

Threshold $K_p \geq 6$

The Kp index indicates the magnitude of geomagnetic disturbance on a 0-9 scale, with zero being very quiet and 9 indicating a major geomagnetic storm. The index has a three-hour cadence. Higher values of Kp are associated with geomagnetic storming



$$1 \text{ nT} = 10^{-5} \text{ Gauss}$$



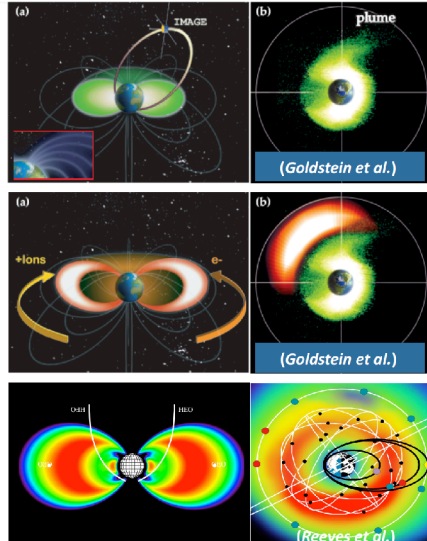
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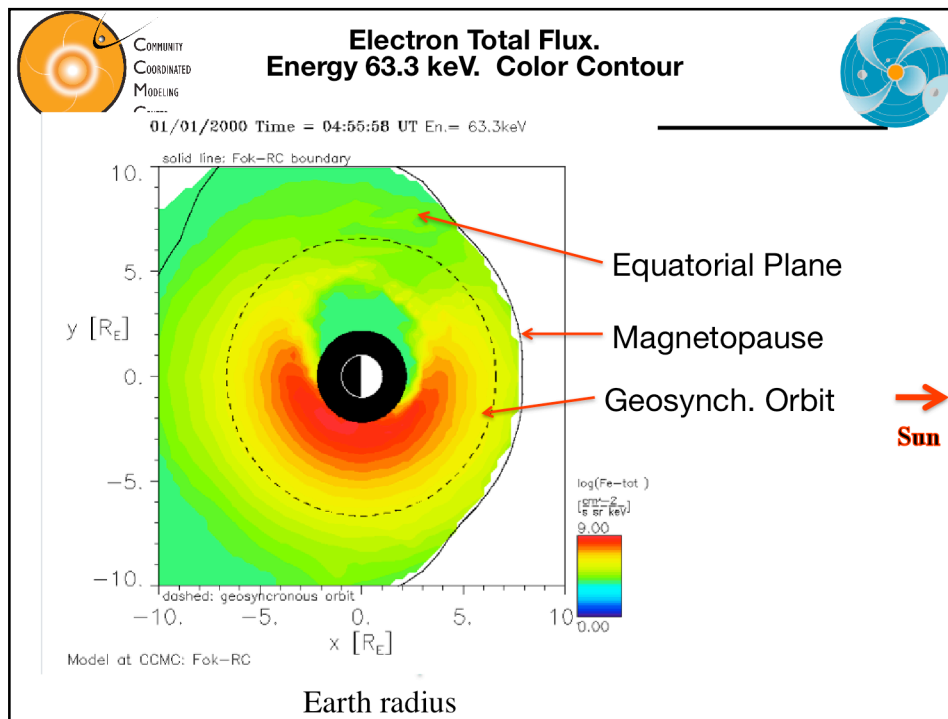
Inner Magnetosphere Plasmas

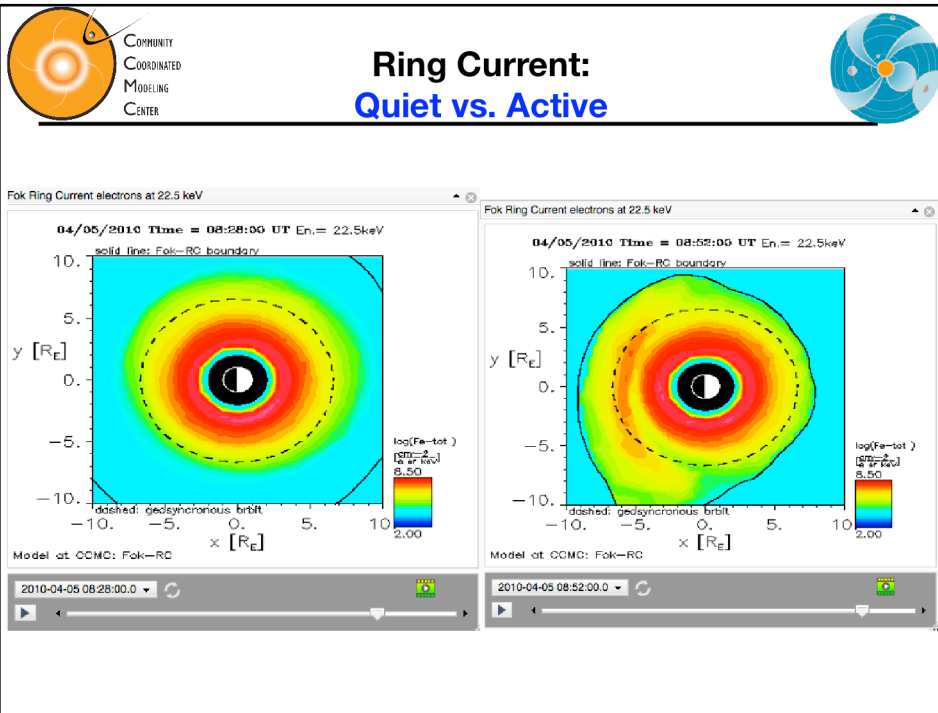


- Plasmasphere
 - 1-10 eV ions
 - ionospheric origin
- Ring current
 - 1-400 keV ions
 - both ionospheric and solar wind origin
- Outer radiation belt
 - 0.4-10 MeV electrons
 - magnetospheric origin

Inner magnetosphere: Gigantic
Particle accelerator





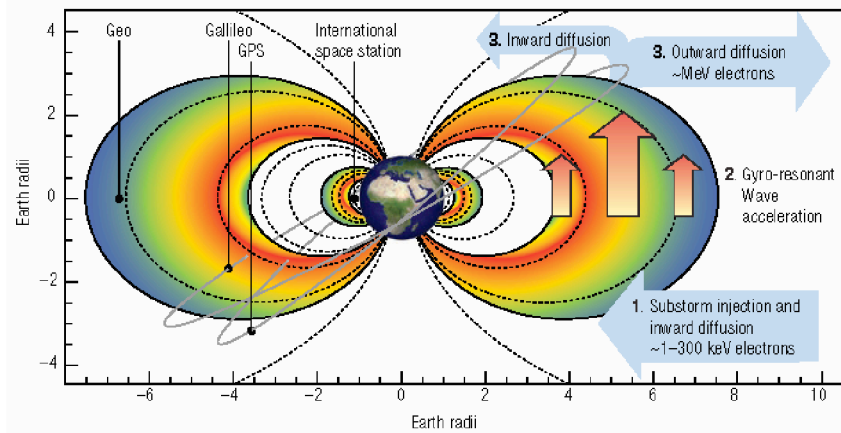




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Electron acceleration in the outer radiation belt



Horne et al., 2007, Nature Physics



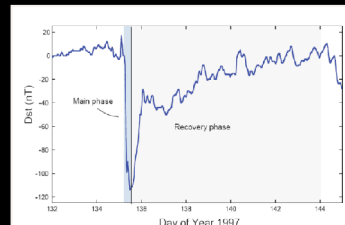
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Magnetic Storms



- Most intense solar wind-magnetosphere coupling
- Associated with solar coronal mass ejections (CME), coronal holes HSS
- IMF Bz southward, strong electric field in the tail
- Formation of ring current and other global effects

- Dst measures ring current development
 - Storm sudden commencement (SSC), main phase, and recovery phase
 - Duration: days



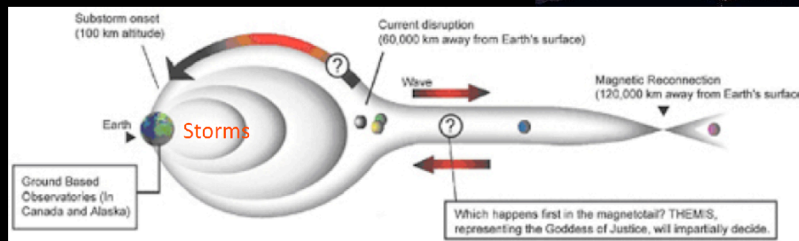


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Substorms



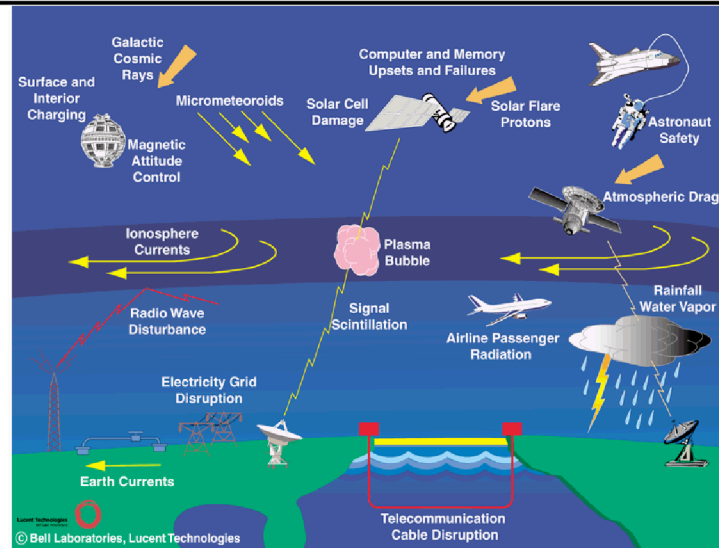
- Instabilities that abruptly and explosively release solar wind energy stored within the Earth's magnetotail.
- manifested most visually by a characteristic global development of auroras
- Last ~ hours



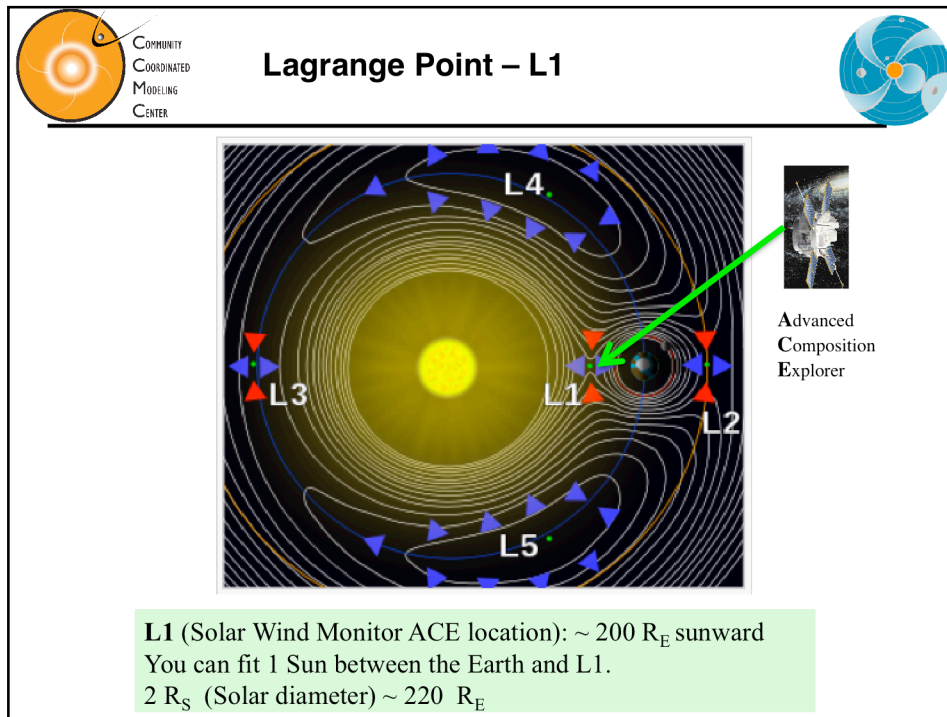


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Space Weather Impacts



Space weather impacts (credit: L. Lanzerotti/Bell Labs)

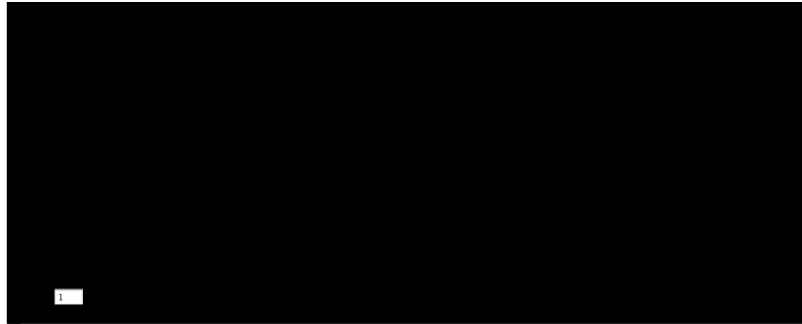


The **Lagrangian points** (**L-points**) are the five positions in an orbital configuration where a spacecraft affected only by gravity can maintain its position relative to the two massive bodies (the Earth and the Sun). You can almost fit 1 solar diameter ($\sim 200 R_E$) between the Earth and L1. Solar wind monitor ACE is positioned at L1 point. It takes about 30 – 60 min (depending on the speed of the solar wind) for the disturbance observed at L1 to reach the Earth.

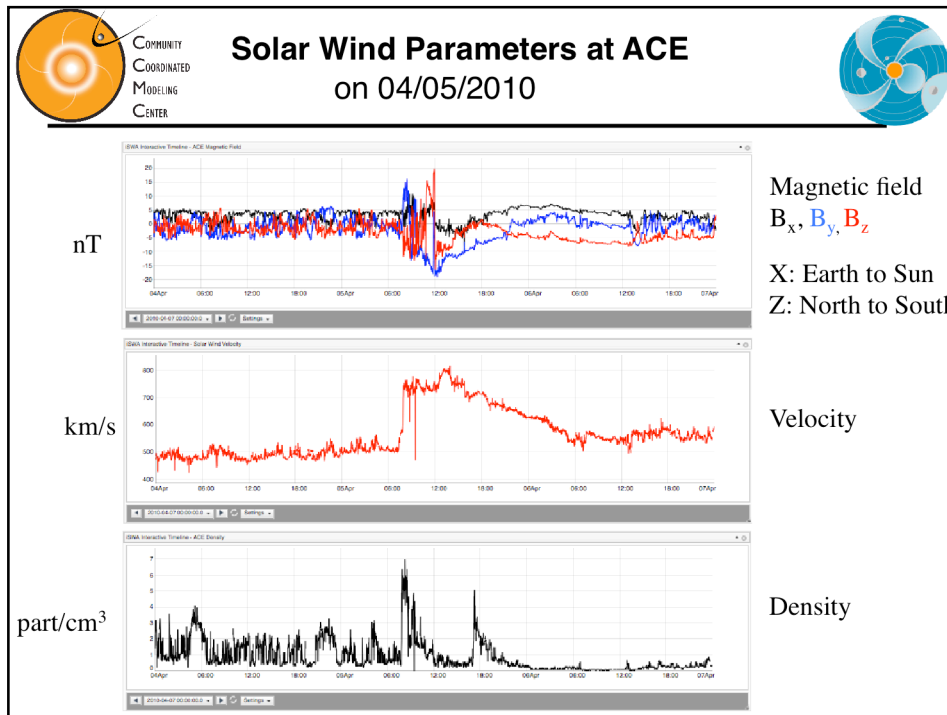


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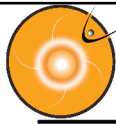
Solar Wind Speed at ACE



☒ Bulk Speed Zoom: [In](#) [Out](#) [full](#) Pan: [left](#) [right](#)



$$1 \text{ nT} = 10^{-5} \text{ Gauss}$$



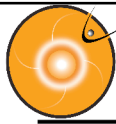
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Magnetopause Stand-off Distance



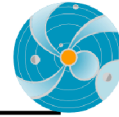
Degree of compression of MP due to dynamic pressure of solar wind





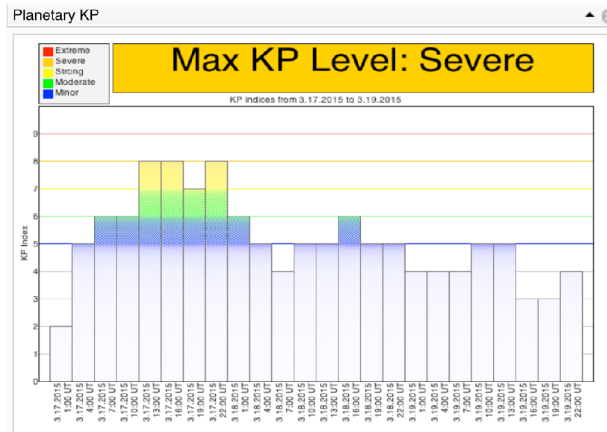
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Kp index

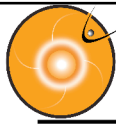


"planetarische Kennziffer" (= planetary index).

- Geomagnetic activity index - range from 0-9 disturbance levels of magnetic field on the ground – currents

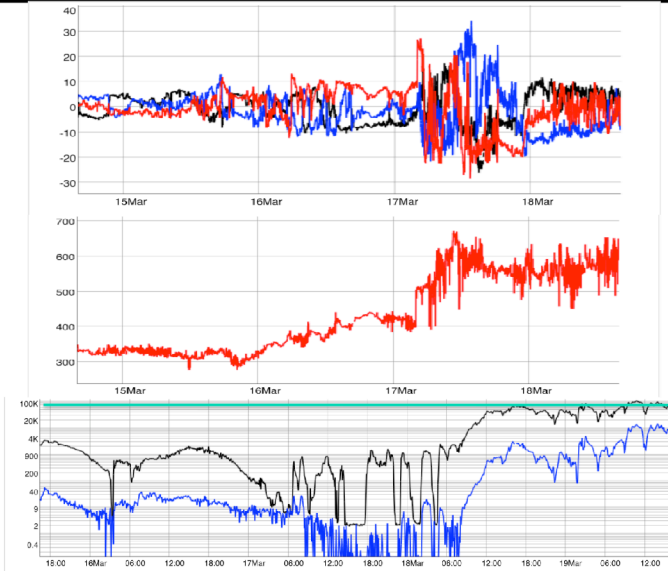


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HSS and Radiation Belt Electron Flux Enhancement



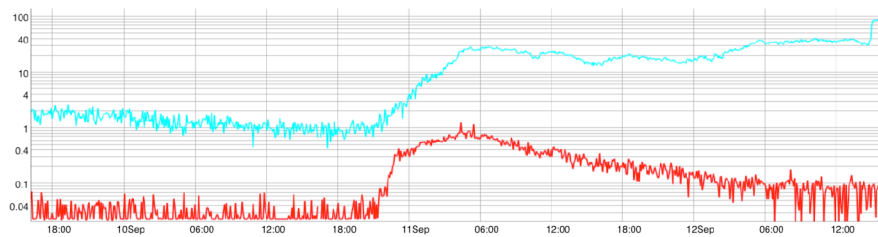
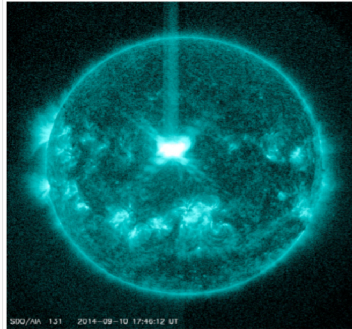


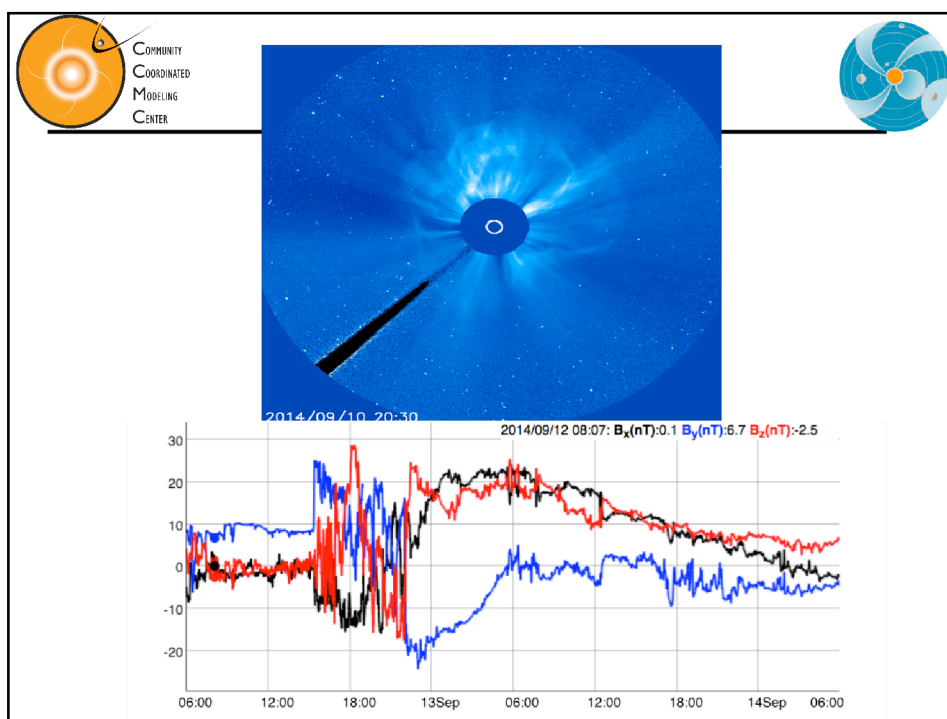
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Energetic Proton Flux



- >10 MeV flux by GOES spacecraft
Threshold: 10 pfu
- >100 MeV flux by GOES spacecraft
Threshold: 1 pfu







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Watch the video



<https://vimeo.com/31377109>

The Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth.

The magnitude of the magnetic varies over the surface of the Earth in the range 0.3 to 0.6 Gauss.



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iSWA Layout:
07/12/2012

<http://goo.gl/CQ6MBZ>